Performance and stability of wheat variety mixtures: a multivariate analysis

Laura Stefan, Silvan Strebel, Yann Imhoff, Lilia Levy Häner

Agroscope, Switzerland

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Département fédéral de l'économie,
de la formation et de la recherche DEFR
Agroscope

L'INSTITUT agro Rennes Angers

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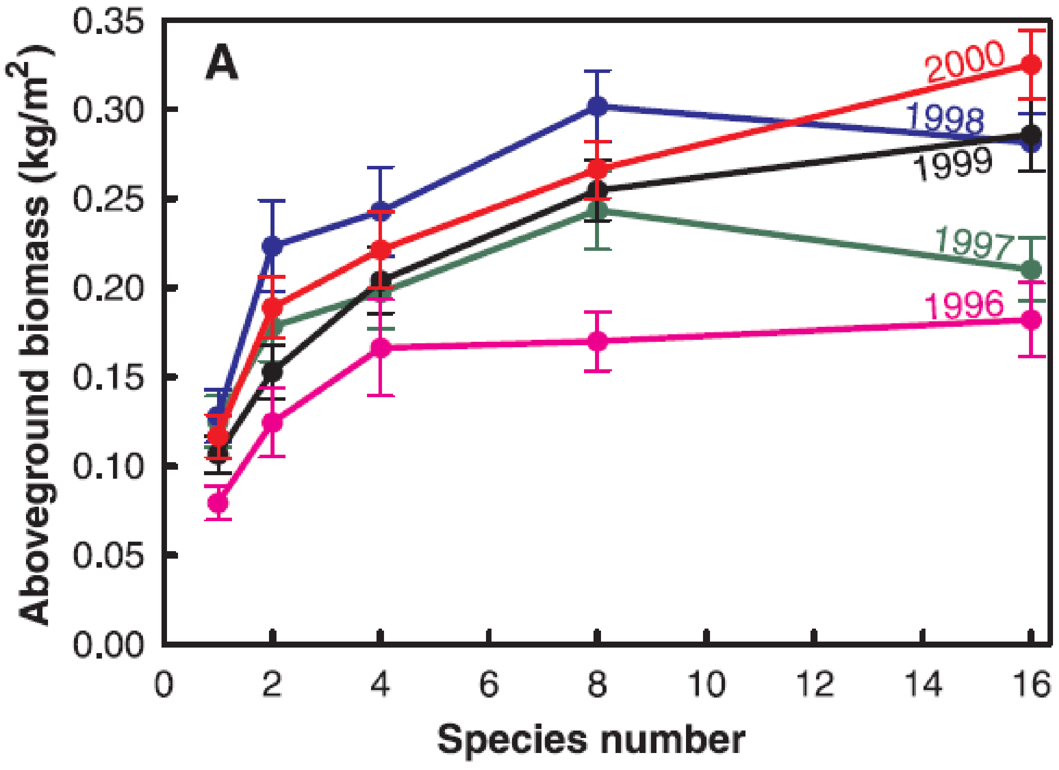
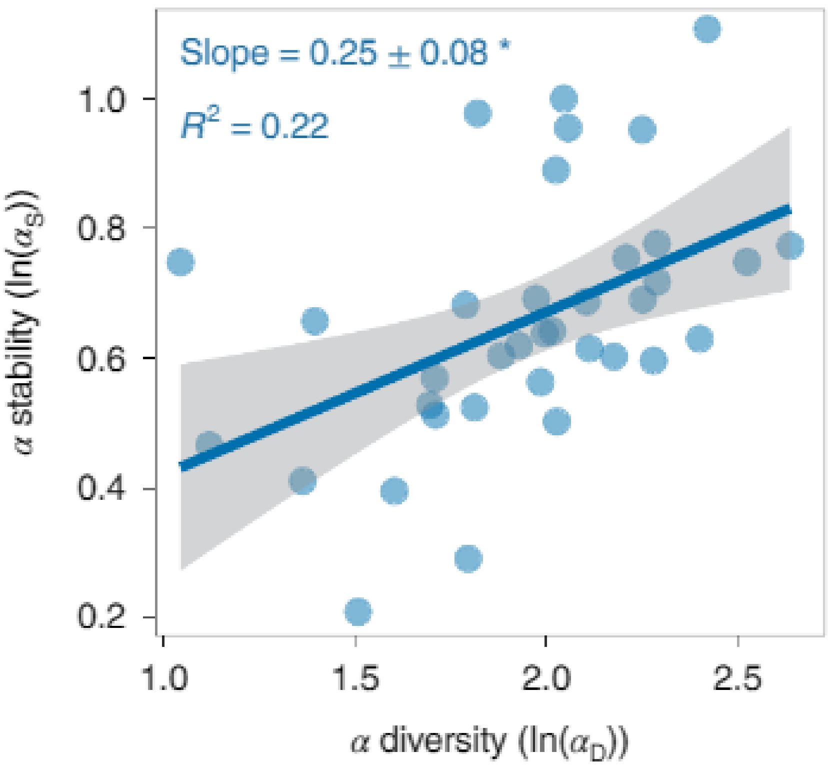
Why use variety mixtures?

- Diversity increases productivity and stability



Tilman et al. 2001



Liang et al. 2022

Why use variety mixtures?

- STABILITY: Compensatory mechanisms
- PRODUCTIVITY: Resource complementarity & Selection Effect
- PRACTICALITY: Easier than species mixtures, no need to adjust harvesting techniques

Why are variety mixtures NOT used?

→ In CH, only 2% of wheat surface is mixtures

→ No general rule to know which mixture would work well

Research goals:

→Investigate role of variety mixtures to increase crop **productivity, quality,** and **stability**

→Investigate the mechanisms underlying the effects

Experimental design

- 8 Swiss wheat varieties
- 28 2-variety mixtures
- 1 8-variety mixture

• 3 repetitions in 3 places for 3 years (2021, 2022, 2023)

= 9 environments

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Experimental design

Crop response parameters:

- Grain yield (dt/ha)
- Protein content (%)
- Thousand Kernel Weight (g)
- Hectoliter Weight (kg/hl)
- Zeleny sedimentation value (ml)

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→ Overperformance of these parameters (e.g. overyielding)

→ Stability using WAASB scores *(Olivoto et al., 2019)*

→ Multitrait Stability Index (MTSI)

Experimental design

Explanatory variables:

- Height at flowering
- Heading day
- Ear density at maturity
- Leaf Area Index

Results: Mixtures performance

	Changins	Delley	Utzenstorf	2021	2022	2023	Average
Overyield	**1.7**	-0.9	-0.5	**0.59**	-0.34	-0.01	0.08
Overprotein	0.023	**-0.3**	-0.06	**-0.17**	-0.07	-0.1	**-0.11**
OverTKW	0.07	0.07	-0.056	**-0.29**	**0.22**	0.16	0.029
OverHLW	-0.55	0.016	0.095	0.078	-0.066	-0.44	-0.14
OverZeleny	-0.15	**1.5**	**1.86**	0.035	**2.18**	**1.03**	**1.08**
OverLAI	**0.3**	NA	NA	**0.55**	0.035	**0.14**	**0.3**

→ Global benefits for Zeleny in mixtures

Stefan et al., in review, preprint [doi.org/10.1101/2024.07.22.604587](doi.org/10.1101/2024.07.22.604587)

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→ Global benefits for Zeleny in mixtures
→ Global disadvantage for protein content
→ Global increase in LAI in mixtures → Better light interception

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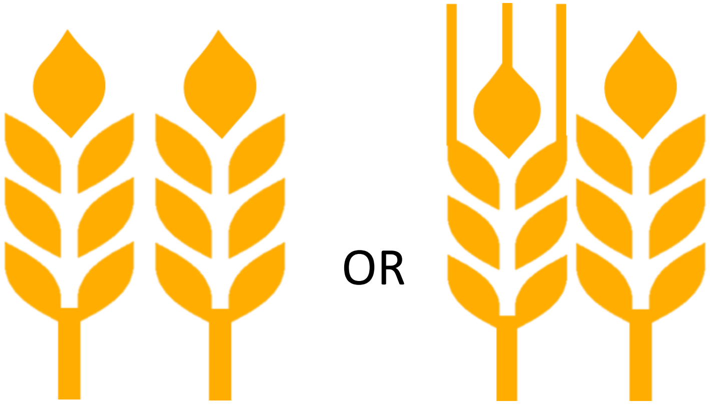
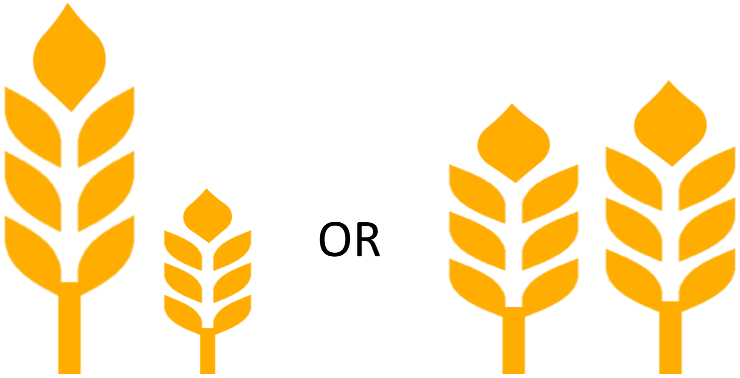
Results: Mixtures performance

Which variety traits are good to combine ?





Stefan et al., in review, preprint doi.org/10.1101/2024.07.22.604587

Results: Mixtures performance

	Overyield	*Overprotein*	*OverTKW*	*OverHLW*	*OverZeleny*
Awns difference					
Diff in mono yield		+			+
Diff in mono protein		-			
Diff in mono height	-			-	
Diff in mono heading day			-		-
Diff in mono density		+			
Diff in mono LAI early					
Diff in mono LAI late					
OverLAI early		+			+
OverLAI late	+		-		

→ Advantageous variety mixtures with components of **similar plant height and phenologies**

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→ Advantageous variety mixtures with components of **similar plant height and phenologies** but **different yield potentials and ear densities**

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OverLAI late	+		-		

→ Advantageous variety mixtures with components of **similar plant height and phenologies** but **different yield potentials and ear densities**

→ Importance of **light absorption** (overLAI) and better ability of mixtures to capture light

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Results: Mixtures performance

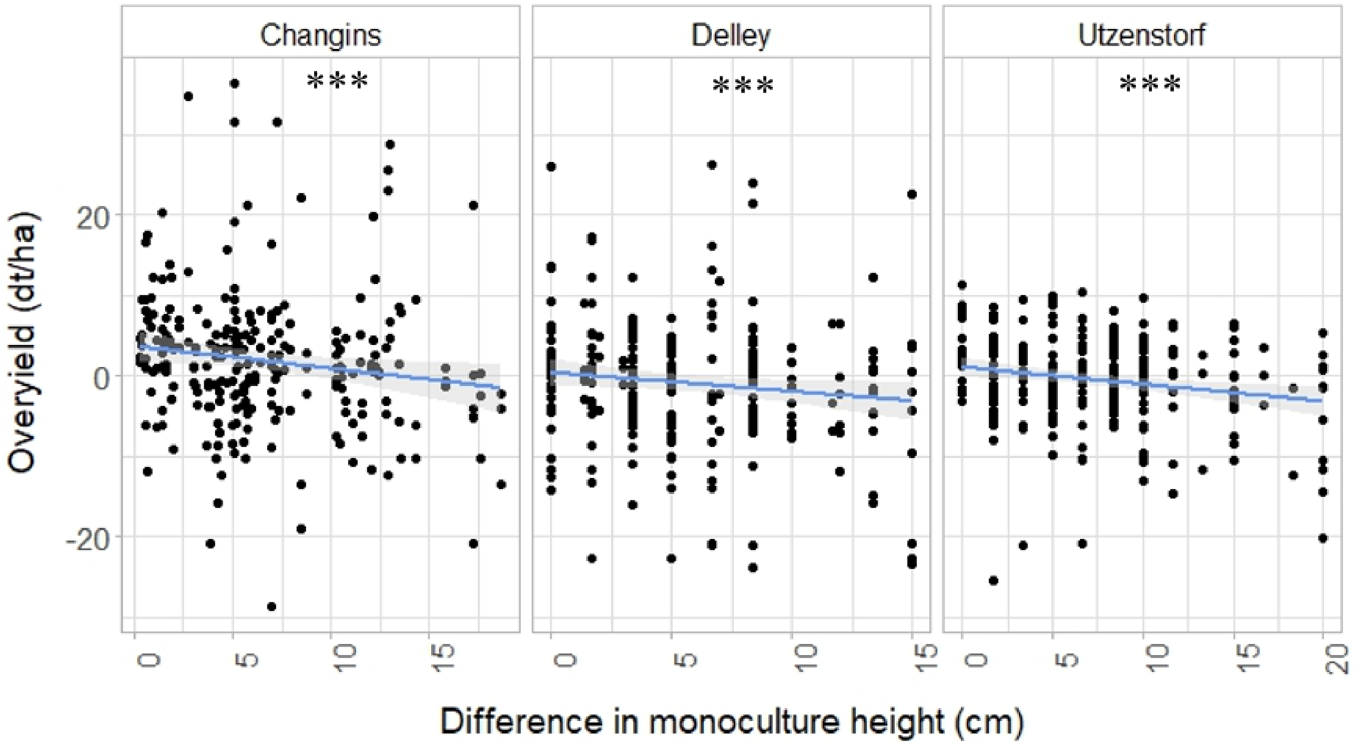

Fig. 1: Grain overyield (dt/ha) of the mixtures in relationship to the mean difference in height of the corresponding varieties when grown in monocultures (cm), in Changins, Delley, and Utzenstorf. n=754
The lines represent linear regression fittings, with the grey area representing the 0.95 confidence interval. Stars represent significant relationships at p-value < 0.05.

→ Overyielding is higher when mixing varieties with **similar heights**

→ Light competition, no need for shorter varieties to compensate by growing more stem at the expense of grains

Results: Mixtures performance

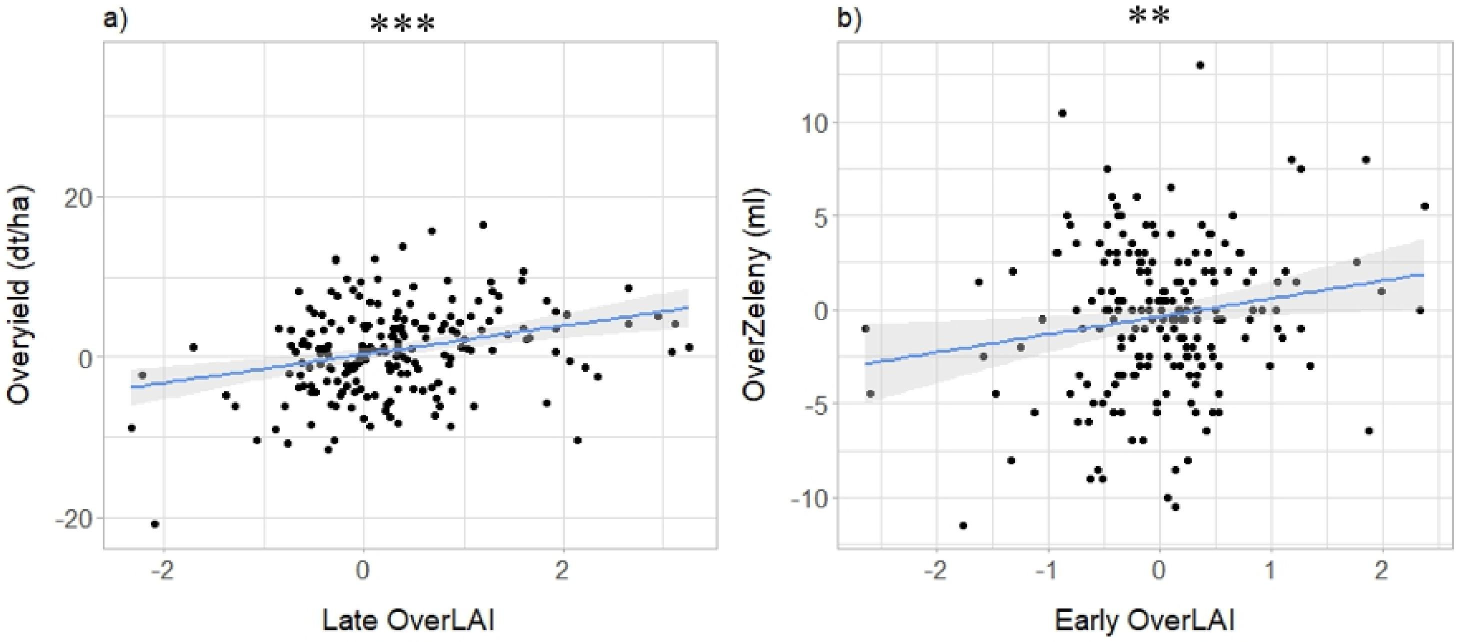

Fig. 2: Grain overyield (dt/ha) (a) and overZeleny sedimentation value (mL) (b) of the mixtures in relationship to overLAI (Leaf Area Index) in Changins. n=246
The lines represent linear regression fittings, with the grey area representing the 0.95 confidence interval. Stars represent significant relationships at p-value < 0.05.

→ Overyielding is higher when overLAI is higher, i.e. when the mixtures are **better at intercepting light** than the relative sum of their components

→ But… what is driving this increase in light interception in some mixtures? **Plasticity in ear density? Tillering ability?**

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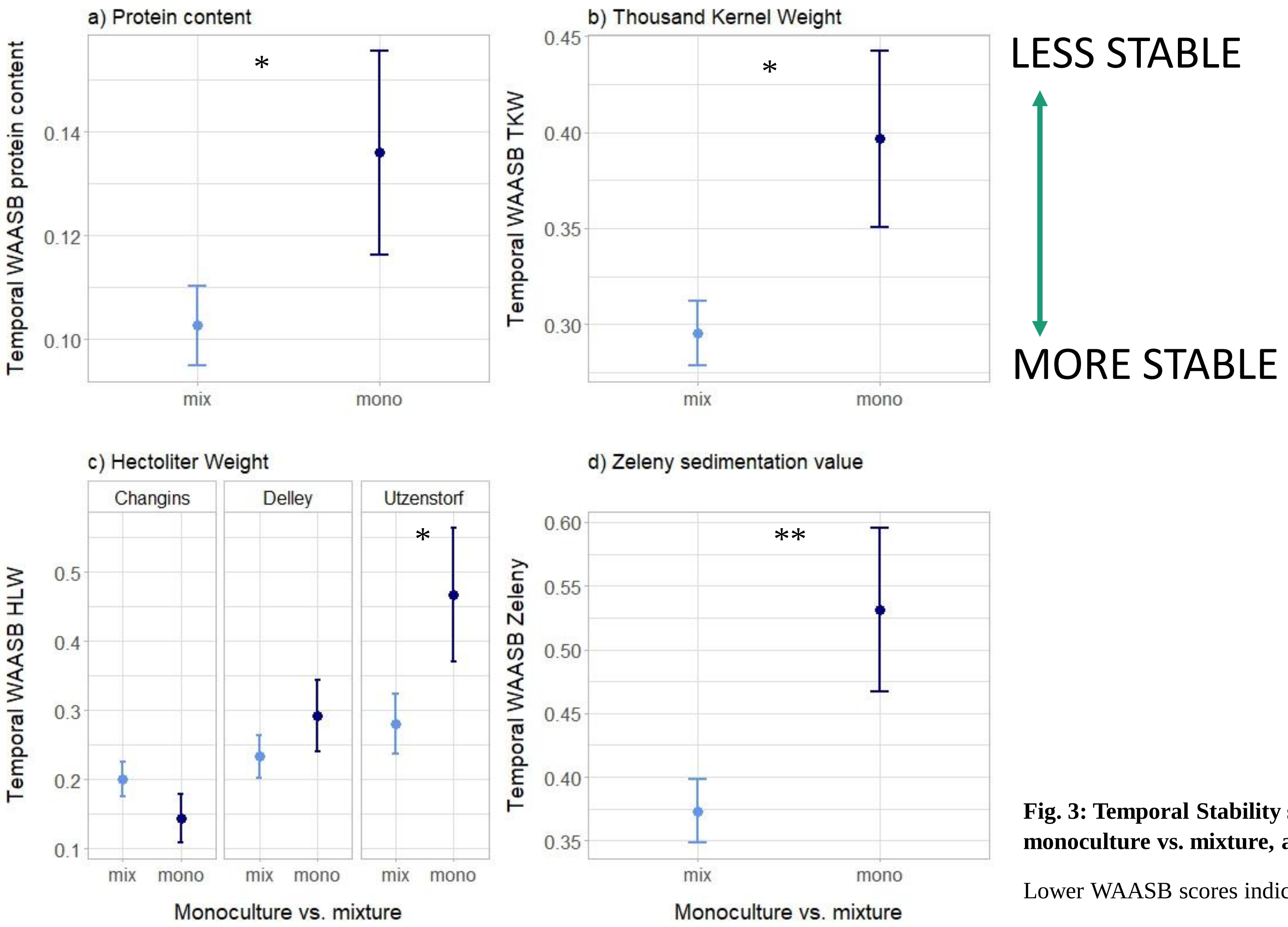
Results: Mixtures stability



Stability in many parameters **higher in mixtures** compared to monocultures

→Especially true for TKW and Zeleny

→Results are valid across different scales (temporal, spatial, global)

Fig. 3: Temporal Stability scores for protein content (a), TKW (b), HLW (c), and Zeleny (d) in response to monoculture vs. mixture, and to site for HLW. n=111

Lower WAASB scores indicate higher stability.

Results: Mixtures stability

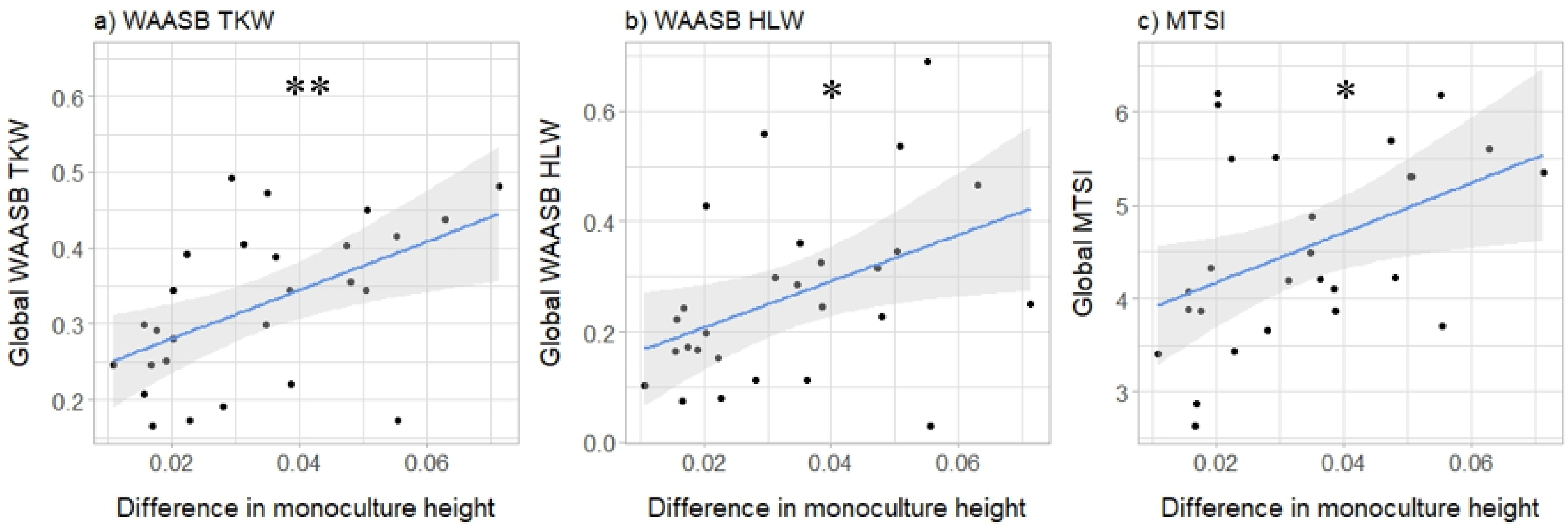


Fig. 5: Global Stability scores for TKW (a) and HLW (b), as well as Global Multitrait Stability Index (c) of the mixtures in relationship to difference in monoculture height. n=28

Lower WAASB scores indicate higher stability.

The lines represent linear regression fittings, with the grey area representing the 0.95 confidence interval. Stars represent significant relationships at p-value < 0.05.

→ Stability higher when varieties have **similar heights**

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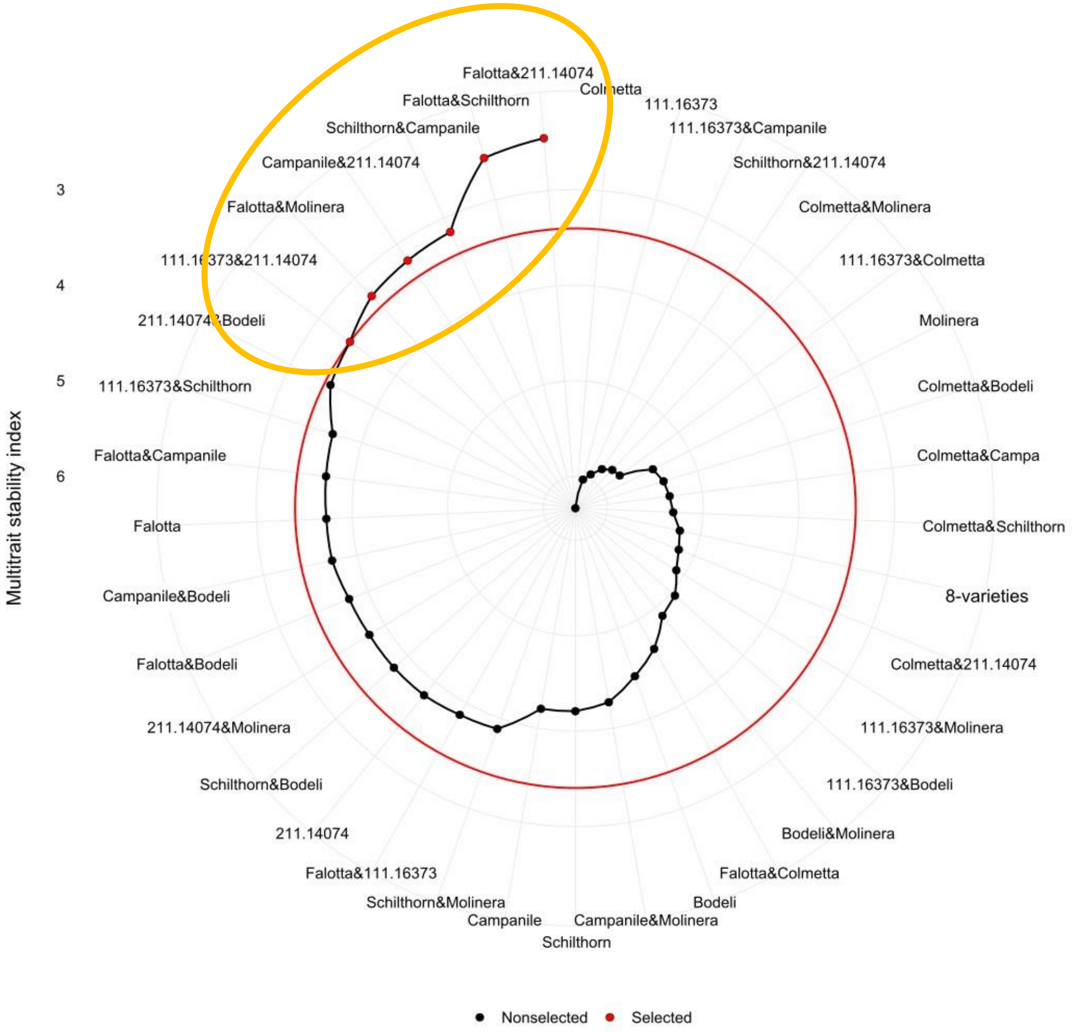
Results: Global performance & stability



- Global ranking of mixtures and varieties for stability and performance of the 5 response parameters
  → **practical recommendations** for Swiss farmers

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Conclusions

- **Mixtures generally outperformed pure stands** in terms of **global performance and stability** for the 5 response parameters
- Especially good for stability and the **stability of grain quality**
- Role of **better light interception** in the mixtures for increased benefits
- Still a **high variability across environmental conditions**
- **Practical rules for variety combinations**: similar heights and phenologies, but different tillering abilities and yield potentials!

Many thanks to my team, colleagues and partners !

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